OTS: 60-31,880

JPRS: 6175

3 November 1960

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- POLAND -

Distributed by:

OFFICE OF TECHNICAL SERVICES
U. S. DEPARTMENT OF COMMERCE
WASHINGTON 25, D. C.
Price: $0.50

U. S. JOINT PUBLICATIONS RESEARCH SERVICE
1636 CONNECTICUT AVENUE, N. W.
WASHINGTON 25, D. C.

F O R E W O R D

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JPRS: 6175

CSO: 3524-D

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[Following is a translation of an article by Witold Zawadowski in Polski Tygodnik Lekarski (Polish Medical Weekly), Vol. XV, No. 8, Warsaw, 1960, pages 3-15. This is Part II of an article published in JPRS 3418-D.]

While the development of man on the terrestrial globe enters the atomic era - and we seem to be standing at the threshold of it at present -, the effect of ionizing radiation on the living organism arouses general interest.

We call ionizing radiation the kind of radiant energy which is emitted through natural radiating elements (uranium, radium, thorium, actinium, potassium and other) and through artificially created radiating isotopes of periodically arranged elements. This includes also X-rays discovered by Wilhelm Konrad Roentgen and the all-pervading cosmic radiation which reaches us from outer space. The common characteristic of all these radiations is their relatively high level of power, very small size of the wave length, high penetrating capacity and their effect on the atomic structure with regard to matter itself. This action consists in extracting and ejecting electrons from their atomic orbit or in shifting their orbit, which results in a temporary disturbance of the atom and its ionization. For this reason, the term "ionizing radiations" was accepted as applying to this entire group of actions.

The present development of measurement techniques enables us to determine accurately the quality of ionizing radiations and to measure their quantity. For that purpose, we use various units of measurement such as roentgen (r), rem and radium, and curie (c) to measure the radiation capacity. We also use smaller units such as milliroentgen, microroentgen, millicurie and microcurie, and larger units such as kilocurie. The latter is used to determine very strong sources of radiation.

The effect of such radiations on living organisms is analogous to the effect on solutions of salts containing oxygen and on colloidal substances. The physical phase of such action corresponds to atomic disturbance and ionization, when a given solution or living

tissue passes through a change. This phase is promptly replaced by a physio-chemical and chemical change. Powerful chemical reactions take place which produce chemically active and free molecules such as OH, O_2H, SH and other. Chemical changes of living organisms produced by such agents damage the living substance, i.e. the cell's nucleus and protoplasm. Depending on the degree of such damage, the cell will survive and recover, or it will perish. The latter phenomenon takes place when chemical action on the cell's small organs in the nucleus and in the protoplasm is sufficiently strong and brings about changes which are irreparable.

Modern radiobiology has at its disposal more than half a century of experience. There are accurate descriptions of types of injury to cells and their little organs, injuries of tissue, their course and consequences, and injuries of more complex organs such as for example sensory organs (eye).

We can name a whole series of various types of damage which result in changes in the organism of higher animals and of human beings, and for practical purposes we can classify them in certain groups. Each of them reflects a different action and course, intricate processes and consequences of its own. In this classification, we take into consideration the following factors: extent of the effect (more or less extensive local damage and general alterations), intensity, duration of the action and size of the dose, i.e. those parameters which have a decisive effect on the course of the damaging alteration and on its general and local consequences.

We can differentiate the following types of harmful action:

a - R a d i a t i o n d i s e a s e. This is a general undoing of the organism after the radiations have affected either the entire body or specific sizeable parts of the body. The severity of the course of the illness is determined by the amount of the dose and by the volume of the affected part of the organism. The destruction is caused by the fact that toxic substances resulting from the decomposition of the damaged fiber were absorbed by the organism. In most frequent cases of a radiation disease, when a large dose has affected the entire organism, there are, in addition to the general toxic effect of the products of decomposition of the cells, symptoms of a considerable damage of the entire blood-producing organ and of the digestive system as well as of the sexual glands, and sometimes there is also depilation.

The reaction takes a violent course and often results in death. Under peace time conditions, the post-radiation disease occurs at the time of accidents in atomic reactors, and in exceptional cases after test explosions of atomic or hydrogen bombs. Studies of the radiation disease are so important that there are departments in Scientific Institues which are engaged exclusively in studying the problem (Chair. of Prof. Kozlowa in the Institute for Additional Training of Physicians in Moscow). In

Poland, such injuries have not occurred as yet in establishments of nuclear physics. Also, there is no research center which would study the problem of radiation disease.

b) L o c a l d a m a g e in an acute or semi-acute form, resulting from ionizing radiation. This occurs when a strong radiation dose has affected unintentionally a small area of skin or subcutaneous fiber. Factors which cause such damage are usually radiations from X-ray lamps used for diagnostic or therapeutic purposes, and sometimes radiation from radium. The skin usually turns strongly red, then there is a localized reaction in the form of a blister, followed by a gangrene of the skin and of the subcutaneous tissue. Such changes heal only after years, usually after surgical and plastic operations. Such damage is later followed by destruction of the tissue or the so-called hardened swelling (oedema induratum). Sometimes, secondary complications occur in the vicinity of the damaged areas, resulting in new ulcerations or developing into new forms of alteration (cancer, sarcoma, see below).

Local damage, which formerly was very frequent, now occurs only quite exceptionally. It may happen now when an overdose is taken unintentionally, when using a radiation beam without filter, or when the physician is not trained. There were several such bases in the last years in Poland. In order to prevent them, short courses were given to surgeons and other physicians to complete their training in the use of X-ray machines. In cases resulting from a therapeutic treatment, usually the laboratory technician committed an error by not using the filter correctly. These rarely occurring regrettable cases do not have any major social significance, because they happen only exceptionally. Such cases usually give rise to a court litigation. The injured person claims incompetence on the part of the physician, and files a civil suit for damages. Such cases can be prevented through better training of physicians, who can take short courses to learn how to operate X-ray machines, and by forbidding the use of X-ray machines by those physicians who did not receive such training. Regulations were issued with regard to the use of portable machines in surgical divisions. Specialized radiologists working in regional offices are obligated to verify during their visits that physicians, who are not rentgenologists and who use X-ray machines, have received the appropriate training.

Such injuries could be avoided, if bed-side machines and instruments used in the operating room were equipped with electronic instruments which increase the picture's strength. By using electronic equipment, we can reduce considerably the radiation intensity. In addition, we can use such instruments without darkening the room.

c) C h r o n i c d a m a g e resulting from prolonged action of repeated small doses. Such cases occurred quite frequently during the first years of the X-ray era. They were caused by the fact that the effects of ionizing radiation were not known. In those days, there were no protective measures taken, and physicians using X-ray machines and taking X-ray pictures were exposed to the effects of large doses of radiation resulting from the cumulative effect of weak radiations received repeatedly. These doses are estimated at a thousand r, three thousand r, four thousand r within a few years. The organs which were most exposed to the radiation was the physician's face, his eyes, hands, and sexual organs. The result was destruction of the skin of the hands and face, excessive hardening of the skin (hyperkeratosis), changes in pigmentation and telangiectasis in the form of dark red spots. In time, superficial tumors appeared which did not heal, then deeper ulcerations showed up. Frequently, the sight was dimmed due to the effect of radiation on the eye lenses. Also, there was azoospermia and sterility affecting both men and women. This group of harmful effects includes also permanent and irreparable damage to the marrow due to the effects of ionizing radiation continuing for many years. The damage to the marrow continued to increase and resulted in leukopenia and aplastic anemia and finally in death. Lesser damage of this type results in a decrease of the organism's resistance capacity, and the course of contagious diseases was more severe in the case of persons exposed to radiation.

Such harmful effects are at present unknown among experienced roentgenologists who use regularly protective equipment (protective pulpits, aprons, gloves, etc.) and operate modern machines. The result of improved X-ray machines is that such harmful effects do not occur now.

Isolated cases involving such changes are observed at present among physicians specializing in other fields, most frequently among surgeons when they start their practice and use obsolete and inadequate instruments without applying any protective means.

Such harmful effects will be prevented, if physicians who are not roentgenologists are trained better or receive additional instructions, and if persons without training are forbidden to use X-ray machines.

d) L o c a l h a r m f u l e f f e c t s o n c h i l d r e n a n d y o u n g p e o p l e, which manifest themselves as a disturbance or retardation of the regular development and growth of certain tissues or organs. Examples of such harmful effects are: arrested development of one breast-nipple gland among young girls, caused by radiation which affected the breast area during the first years of life, arrested growth of an extremity or of one of the long bones, or disturbance in the development of the teeth as a result of irradiation caused by X-rays or radium. The disturbance may

occur after treatment by radiation taken in the early years of life, at which time the treatment did not show any tangible strong effects. A particularly notable example of such harmful effects is retarded phychic development of a child after improperly performed depilation of his head, by using excessive and unnecessarily deep-penetrating radiation. Such harmful effects occur rarely at present. A well-trained roentgenotherapeutist, who has experience in pediatrics, can avoid them by using appropriate methods of treatment.

e) Radiation effects which accelerate the aging process. This harmful effect is well known from experiments performed on animals. It was observed that an animal which had survived the effects of a sufficiently large dose of radiation, showed symptoms of aging very soon after the symptoms of the radiation disease had disappeared. The animal assumed the locks and the characteristics of an old animal, even though it was young in age.

On the basis of observations made by some roentgenologist physicians from the beginning of the radiological era, the phenomenon of premature aging of human beings has been confirmed. It is accepted that a radiation dose of one thousand r, affecting the entire organism over a long period of time, will probably reduce the duration of life by 5 years. The apparent cause of post-radiation aging is a slowly advancing atrophy of blood vessels and poorer nourishment of all tissues, and also a general decrease of life efficiency of the cells in the entire organism. Such harmful effects in time of peace are not of a great social significance, because they do not occur among persons working within the reach of ionizing radiation, if regulations of labor hygiene are observed. If premature aging occurs as a result of accidents in atomic energy establishments, laboratories of nuclear physics, in radiochemistry or in industry, such instances would be undoubtedly only isolated cases, as indicated by our past experience. Our experience gained in the course of time, and the technical improvements which we have introduced, are a sufficient guarantee that the number of such cases will be reduced. It is not likely that the so-called tolerance doses accepted at present could shorten the life of persons working within the reach of ionizing radiations.

f) Cancer-causing effects (oncogenic, carcinogenic).

As we know, tumors can appear under the influence of various factors. These factors are either strictly defined and existing outside of the organism, or they are endogenous. The cancer producing effects of both ionizing radiation as well as visible light and ultraviolet rays have been known for a long time. However, the pathogenesis of tumors caused by radiation is not clear. Tumors can develop under the influence of ionizing radiations in various organs, most often on the skin. We know of numerous cases of tumors

formed on the skin of hands of roentgenologists belonging to older generations. In those days, protective means were unknown and were not used. Today, if roentgenologists observe the principles of labor hygiene, we do not find tumors on their hands. Tumors caused by radiation include also leukemia. As shown by certain statistics, these tumors occurred more frequently among radiologists and roentgenologists of the older generation. These statistics were questioned more recently. We should also mention leukemia shown in persons affected by the Bechterew disease, caused very often by irradiation applied while the person suffered under the effects of this incurable and protracted disease. When the irradiation is carried out schematically and without individual care, unnecessarily large areas of blood-producing red marrow receive excessive doses of radiation.

It is not impossible that the tumors, at least some forms of them, which occur in persons subjected to radiation, develop under the influence of some other etiological factor, and the radiation is only a secondary factor. This is supported by the observation that radiation increases the frequency of tumors among such varieties and stocks of experimental animals, which show a susceptibility to tumor-forming diseases even when they are not exposed to radiation.

Only large doses of irradiation effecting the entire body or large parts of the body result in the formation of leukemia. Therefore there is no need to fear that personnel working within the reach of ionizing radiation may be affected, if labor hygiene regulations are strictly observed and if the safe dose is not exceeded.

Significant data about the occurrence of leukemia are given by the residents of Hiroshima who have survived the atomic bomb explosion (Table 1).

An example of cancer-producing effects of ionizing radiation, which has been known for a long time, is the bronchial cancer occurring among miners in uranium mines (Schneeberg, Jachymov), after long periods of work (on the average, after 17 years).

The cancer-producing and leukemia-producing effects of ionizing radiation sofar does not assume the significance of a widespread social disease.

Table 1

Distance from the place of bomb explosion in m.	Incidence of leukemia per 10,000 persons
Less than 1,000 m.	123
1,000 - 1,500 m	28
1,500 - 2,000 m	4
3,000 - 3,000 m	2
3,000 m or more	1.6
Japanese people not exposed to radiation caused by the explosion	1.5

The situation could change, if the rules of labor hygiene were not observed and the application of industrial and power isotopes was expanded, if some accident occurred in the future after expansion of the network of atomic reactors, or after atomic and thermonuclear explosions of some other origin.

Preventive means used in all establishments of nuclear physics and nuclear energy are very important for the prevention of cancer-producing effects of radiation. These are particularly important in uranium mines (ventilation, constant tests of the contents of radiation-producing (radon in the air of the mine shafts and tunnels, constant check on the miners' health conditions).

In view of the fact that cancer-prouducing effects may appear after a long period of concealment, it is necessary to review indications of mild cases in roentgenotherapy (those without tumors), and to avoid treatment by X-ray radiation in those cases where it would be necessary to use repeatedly large doses of radiation.

g) While all the types of harmful after-effects of radiation described above concern only the person exposed to radiation, the harmful effects described in this category are characterized by the fact that the irradiated person does not show symptoms of damage, but such symptoms are observed only in his descendants, and in most cases in more distant generations. Evidence of damage may be observed (i.e. it may appear in a phenotypic form), only after several generations. The d a m a g e of h e r e d i t a r y t r a i t s appears not only after single large doses of radiation affecting sexual organs, but also after radiations of very small intensity, if such radiations last for a long time or are repeated frequently. Here we have the phenomenon of accumulation of small doses, which cannot be observed in the harmful effects affecting individual persons. It appears that the danger limit of a harmful factor does not apply to harmful effects on genetic organs. Even the slightest radiation spread over a long period of time has harmful effect on the hereditary traits in the form of the so-called mutation, i.e. sudden changes of such characteristics, which as a rule are damaging.

Mutations occur in all living creatures to some extent, regardless of the effects of ionizing radiations affecting sexual organs. Such mutations are generally unfavorable and appear partly in the form of the so-called inherited defects. Sometimes, it may be a general decline of favorable characteristics, such as for example strong stature, efficient physical functioning, resistance to diseases, mental faculties. These latter characteristics are not too tangible and cannot be analyzed exactly for the time being. Visible defects of development of a more advanced degree appear in 2% of births regardless of any radiation. Their causes and their mechanism are not fully clarified at present, since we do not know what independent factors cause mutation.

It has been known for about 30 years (Muller) that the frequency of mutation (visible defects of development) increases under the influence of ionizing radiation. This was found in connection with genetic studies of a small fruit fly (Drosophila). The fly is particularly suitable for genetic studies, because it breeds rapidly, and therefore it is possible to observe a large number of generations which follow in a short period of time. Recent experiments with mice confirmed the facts known previously, and at the same time they disclosed that mammalians are more susceptible to mutations than insects. New studies of the influence of ionizing radiation on the genital organs of some larger animals, carried out in the United States, will give results only after a number of years. The experiments are financed by an endowment of seventeen to twenty million dollars annually, and they are carried on series of 6,000 pigs and several hundred dogs.

As in the past, suggestions concerning human beings are based on experiments with insects and small mammalians, and partly also on observations carried out after the [atomic] bomb explosions over Japanese cities. Nevertheless, opinions of experts in genetics vary considerably as to the harmful amount of a dose. Only within certain limits of probability we can assume that doses received by sexual organs in excess of 10 units of r within the first thirty years of life are clearly harmful, i.e. they increase the frequency of mutation. In evaluating the influence on the sexual organs, we usually accept the effects in the first 30-40 years of life, since about 50% of the children are born in the period up to 30 years of age, another 40% up to 40 years, and 10% over 40 years.

All living creatures on the surface of the earth are subjected to ionizing radiation which forms the so-called radio-active background. This consists of: 1) cosmic radiation; 2) radiation of natural radioactive elements in the air, water and soil; 3) radiation of radioactive elements contained in the human organism itself, such as radium, potassium and radioactive carbon.

A certain amount of radioactivity, about 0.5-1.0 r, is brought to the radioactive background from radioactive dust circulating in the atmosphere after atomic and hydrogen test explosions in the course of 30 years, and about 0.3 r from other sources. A total dose of about 5 r coming from the radioactive background and from other sources affects the sexual organs in the first 30 years of life.

In countries of the highest technological progress, the dose is probably increased to about 10 r. These are absorbed up to the age of 30 through diagnostic and therapeutic treatment in which X-rays are used. These comparisons would indicate that in some capitalist countries there is a danger that the future generations will degenerate. Indeed, the doses of ionizing radiation affecting the sexual organs as indicated by data which may not be entirely accurate, exceed now in those countries in some cases 15 r during 30 years of life. Such doses are clearly not neutral from the genetic point of view. Doses of 30 to 80 r affecting the sexual organs during 30 years are highly dangerous, because they double the number of visible and grave defects of development.

The danger threatening hereditary characteristics and the possibility of an increase of the number of development defects have greatly disturbed scientific, naturalist and medical circles, government circles and also the general public in capitalist societies. Disturbing testimonies of biologists-geneticists were heard. Some scientific organizations formed committees to study the situation. Many institutions, which promote the development of scientific research, have assigned large sums to encourage research work in the field of human genetics. In many countries, whole series of research work concentrate on studying the effects of radiation doses on the sexual organs during roentgenological research. The findings of various scientists vary considerably. Research work carried out in different centers and localities has shown considerable variations in the loading of the sexual organs through radiation used in diagnostics and therapy. For example, the average value of a 30-year load for the entire United States vary in the opinion of various authors between 3 r and 10 r. On the other hand, measurements and calculations carried out in certain smaller places indicated much smaller amounts. For example, in the locality of Richland (a small industrial city in the United States), the loading of the sexual organs is reported to be only 1.4 r during 30 years of life.

Article received on September 18, 1959. Address: Warsaw, ul. Chalubinskiego 5, Zaklad Radiologii (Foundation of Radiology).

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